Instruction Handbook for....

Type 80
NOISE STANDARDS

July 1967

CUTLER-HAMMER

AIRBORNE INSTRUMENTS LABORATORY
DEER PARK, LONG ISLAND, NEW YORK 11729

CONTROL AIL DIVISION

JERRY A. WALCZAK
Loren T. Green & Associates
5218 W. DIVERSEY AVENUE
CHICAGO, ILLINOIS 60639
286-6824

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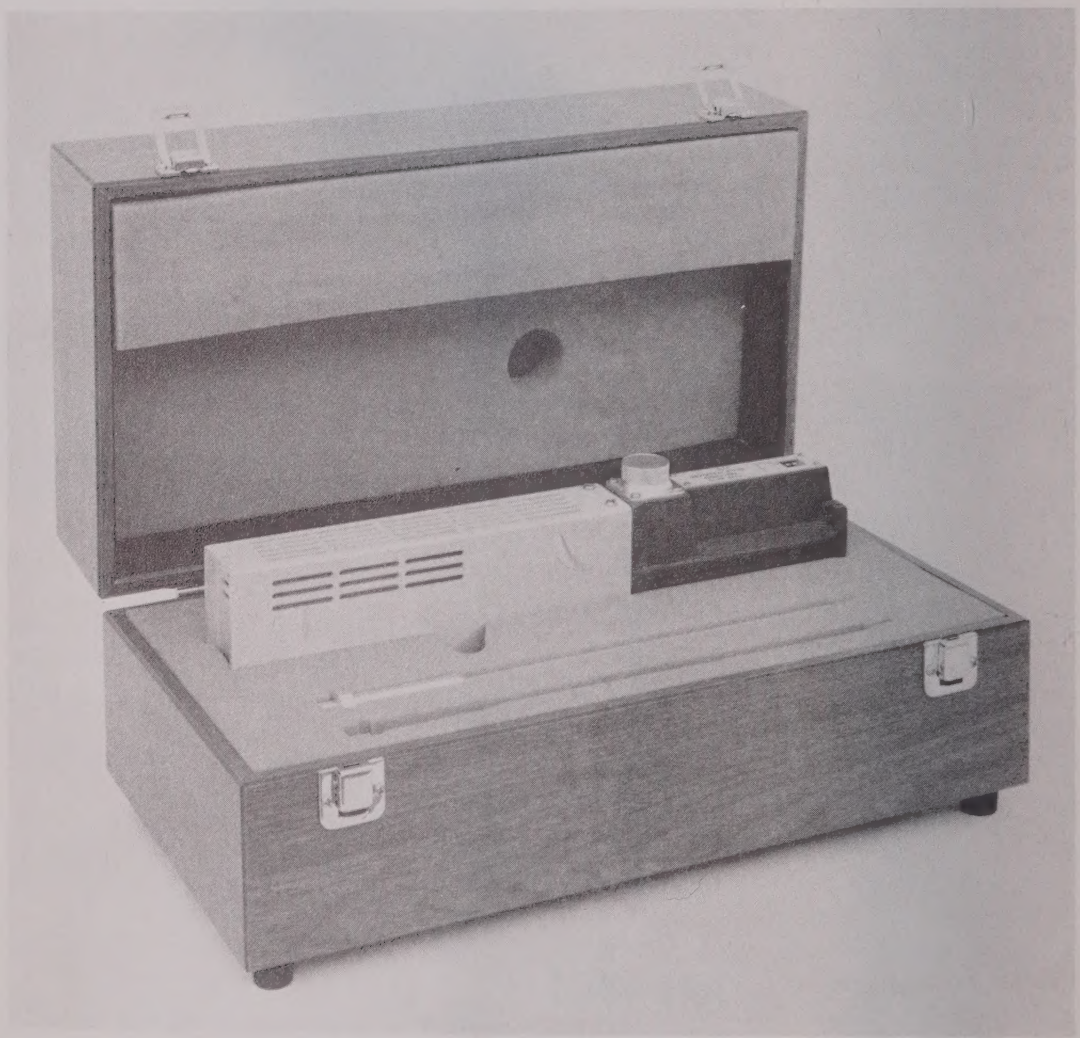

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I. INTRODUCTION

A. GENERAL

The Type-80 Noise Standards are precision sources of random noise suitable for use as laboratory standards and acceptable for calibration by the National Bureau of Standards. Each unit consists of two precisely machined waveguide sections joined at a shallow angle. An argon gas-discharge tube is located on the centerline of one section and emerges through the wide face of the other section.

B. PART NUMBERING

There is a Type-80 Noise Standard (Figure 1) for each waveguide size at which the National Bureau of Standards has calibration facilities. The part number of each Noise Standard reflects its waveguide size and, therefore, its frequency range. For example, Type 8052 (Figure 2) is a Noise Standard whose internal dimensions correspond to RG-52/U waveguide that covers the range from 8.2 to 12.4 GHz.

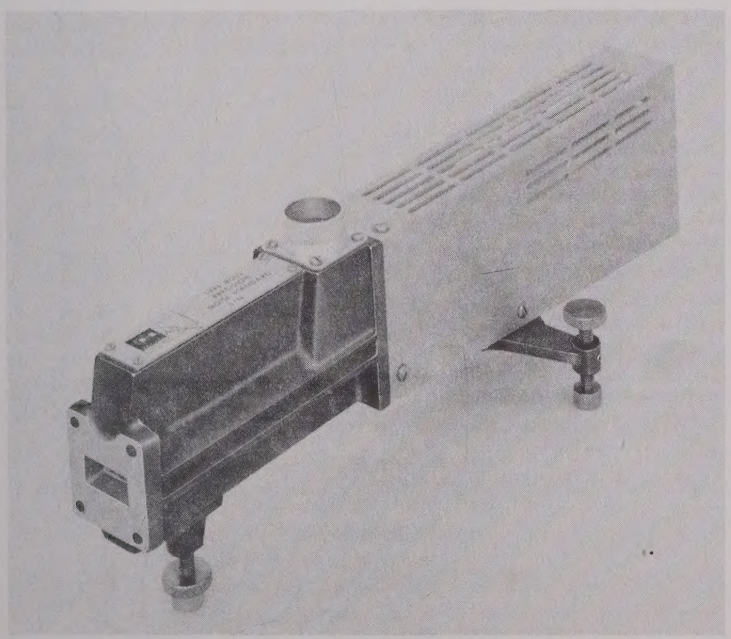


FIGURE 1. TYPE-80 NOISE STANDARD

II. SPECIFICATIONS

Table 1 lists the specifications for the Type-80 Noise Standards.

Part No.	Frequency Range (GHz)	VSWR (note 1)	Effective Output Noise Temperature ^{o}K (nominal)	Noise Temperature Tolerance ^{o}K (note 2)	Power Required	Size (inches)	Weight (pounds)	Shipping Weight (pounds)
8052	8.2 to 12.4	1.10	10,500	$\pm$500	2 kv start pulse 200 $\pm$1 ma operating current. 6.3 v at lamp filament starting power.	12 x 6 x 4	3	6
8091	12.4 to 18.0	1.15	10,900	Same as above	Same as above	12 x 6 x 4	3	6

Note 1 - This is a maximum specification. See Figure 2 for typical plot of VSWR versus frequency.

Note 2 - As obtained from the factory. These units are capable of being calibrated by the National Bureau of Standards to an accuracy of $\pm 250^{o}K$.

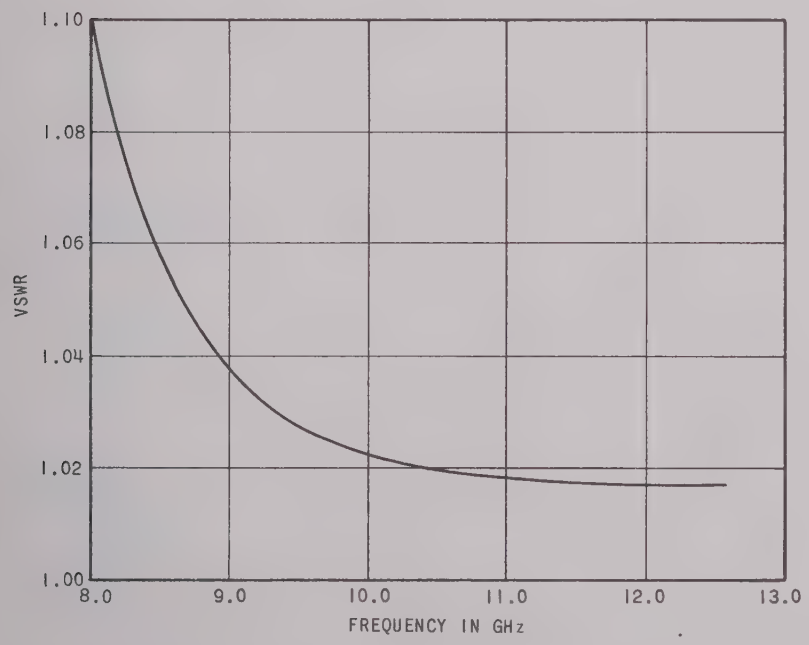


FIGURE 2. VSWR OF TYPICAL STANDARD TYPE 8052

III. TUBE INSTALLATION INSTRUCTIONS

The noise tubes used in the Type-80 Noise Standards are removed from the mounts prior to shipment to prevent shipping damage. Noise tube installation is as follows (Figures 3 through 6):

a. Remove the mount and the tube from the storage container.

b. Remove the four screws holding the heat shield to the rear of the mount, and remove the shield (Figure 3).

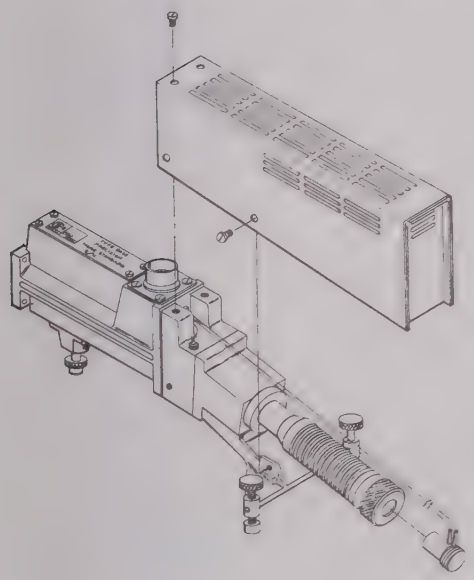


FIGURE 3. HEAT SHIELD REMOVED

c. Unscrew the tube retainer nut from the end of the cathode assembly (Figure 4).

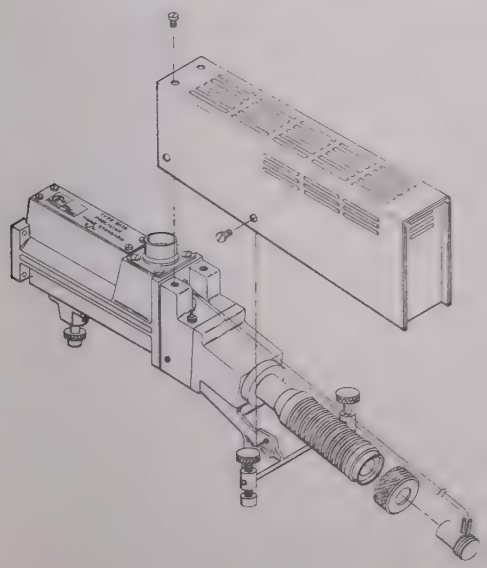


FIGURE 4. RETAINER NUT REMOVED

d. Insert the tube, anode end first, in the mount. There will be a spongy resistance due to the centering "O" rings.

e. Rotate the tube until the keyway on the tube base is aligned with the key on the mount. Seat the tube (Figure 5).

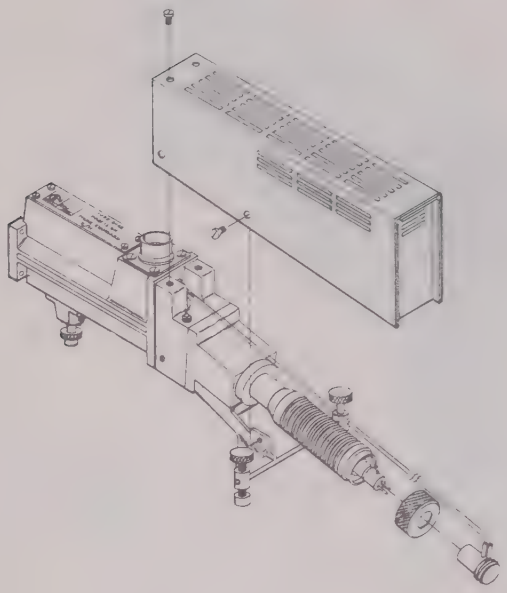


FIGURE 5. TUBE ALIGNED AND SEATED

f. Replace the tube retainer nut and tighten it finger tight.

g. Connect the cathode connector. Make certain the wires exit from the top of the connector assembly (Figure 6).

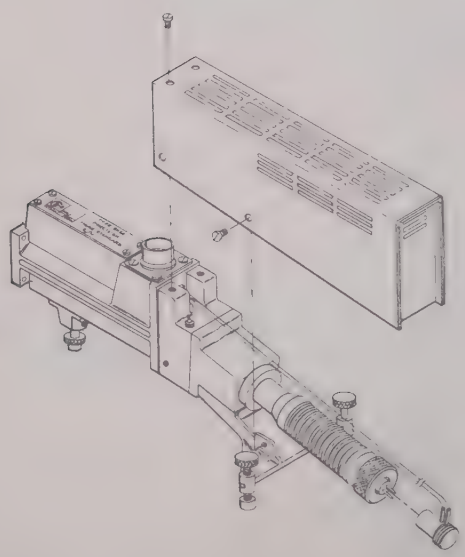
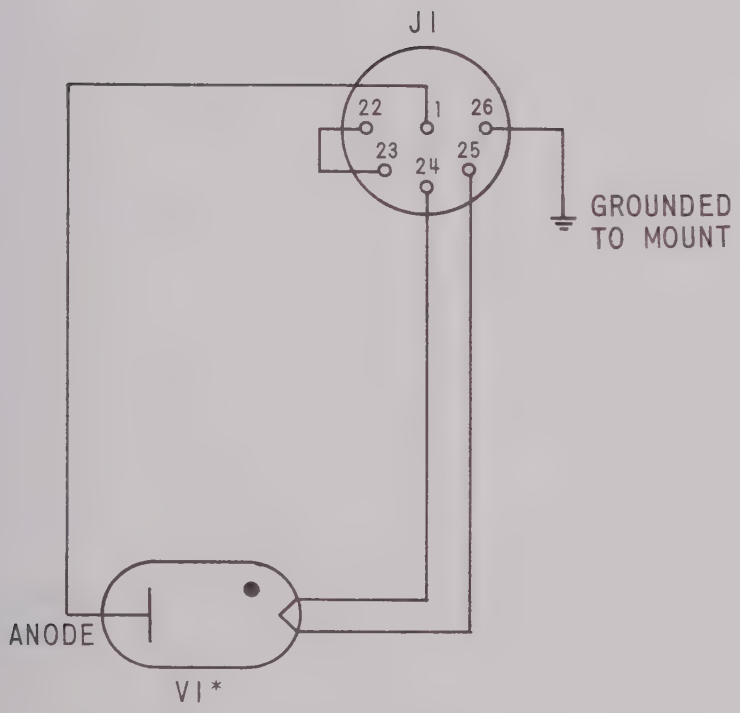


FIGURE 6. MATE CATHODE CONNECTOR

h. Replace the heat shield.



*NOTE: SEE TABLE OF REPLACEABLE PARTS, SECTION IX FOR LISTING OF TUBE TYPES

FIGURE 7. SCHEMATIC DIAGRAM, TYPE-80 NOISE STANDARD

IV. OPERATION

A. GENERAL

To place the Noise Standard in operation after the tube is installed, simply connect the device to the measurement system, make the proper power connections, and energize the unit. In any application requiring high precision, the unit should be energized for at least one half-hour prior to use. This will allow the entire structure to reach thermal equilibrium.

B. POWER REQUIREMENTS

1. Power is supplied to the Noise Standard thru J1--the power connector mounted on top of the output waveguide section. Because of its specialized power requirements, it is strongly recommended that the Type-80 Noise Standards be operated from an AIL Type-81 Noise Source Control Unit. This is a highly stable, current-regulated power source. In addition, the instrument contains the high-voltage pulser and filament power source required for ionization of most gas-discharge noise sources. It should be noted that the precision of the Type-80 Noise Standards cannot be guaranteed unless the power source is at least the equivalent of the Type 81.

2. The power requirements of the Noise Standards are noted in Table 1; however, some clarification is required. The high-voltage pulse source should provide repetitive pulses at no less than 10 pps at the levels indicated. The pulses and filament power are required to initiate ionization of the plasma. Once the noise source is ionized, the pulse and filament power sources may be removed. The current should be held as close as possible to the rated value, since noise output of the source is a function of the operating current. The typical variation of excess noise ratio with current is about 0.003 db/ma.

3. Figure 7 indicates the power connections to the Noise Standards.

V. APPLICATIONS

A. GENERAL

The Type-80 Noise Standards may be used in any application requiring a stable, precise source of high-level microwave noise. Typical applications include: calibration of microwave noise generators, receiver noise temperature and noise figure measurements, and reference sources for high-level radiometric measurements.

B. CALIBRATION OF MICROWAVE NOISE GENERATORS

1. The Type-80 Noise Standards can be used to calibrate the output of microwave noise generators by means of radiometric comparison techniques. A typical setup is shown in Figure 8. Using this system, the difference (in db) between the relative excess noise temperature of the unknown and the standard can be read directly from the front panel dial of the Type-82 Noise Temperature Calibrator.

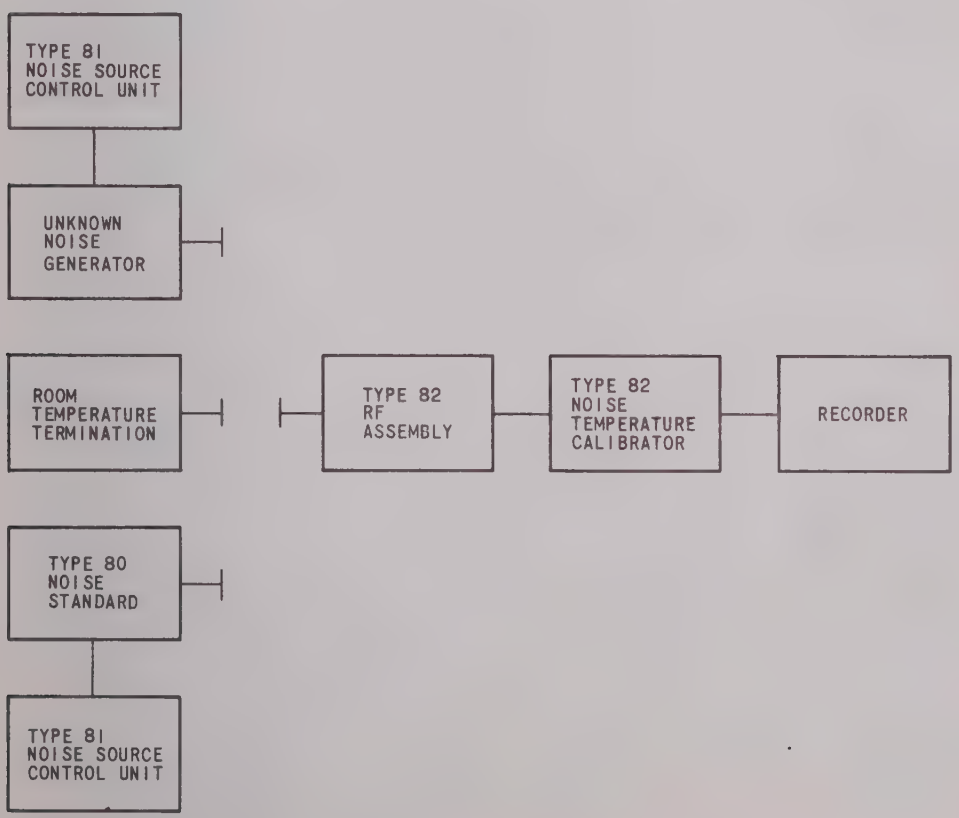


FIGURE 8. TYPICAL NOISE GENERATOR CALIBRATION SETUP

2. The accuracy of the calibration is a function of many factors. One of these, of course, is the accuracy of the Noise Standard. Typically, this is better than $\pm 250^{\circ}K$ (± 0.1 db relative excess noise temperature). Another major factor is the effect of mismatch, in particular, the change in mismatch that occurs when the Noise Standard is replaced with the unknown. The Type-80 Noise Standards exhibit very low VSWR's; typically, less than 1.05 over most of the operating range. With an unknown noise source VSWR of 1.5 the comparison tolerance of this system is better than ± 0.1 db. This results in an overall calibration accuracy of better than ± 0.2 db.

C. RECEIVER NOISE MEASUREMENTS

1. The construction of the Type-80 Noise Standards is such that it is not feasible to incorporate internal terminations. When the Noise Standards are turned off, they are essentially short-circuited waveguides. The Noise Standards, therefore, are not particularly suited for receiver-noise-temperature or noise-figure measurements; however, if the operator is tolerant of some inconvenience, and if considerable care is exercised, they may be used for this purpose.

2. A general setup for manual noise-figure measurements is shown in Figure 9. The procedure is the same as the general Y-factor measurement, except that a separate room temperature termination must be used to set the initial reference.

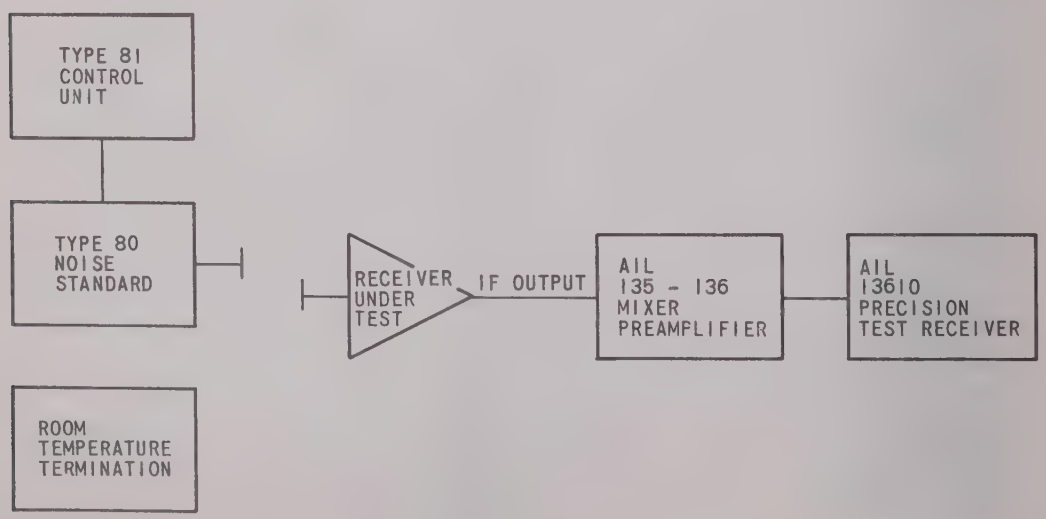


FIGURE 9. TYPICAL RECEIVER NOISE MEASUREMENT

VI. THEORY OF OPERATION

A. GENERAL

The Type-80 Noise Standards are gas-discharge noise sources each using an argon-filled glow tube as the noise-generating mechanism. To be classified as a laboratory standard however, a device must be highly stable and repeatable, and well-matched over the frequency range of interest. It is here that these units differ from the general, commercially available, gas-discharge noise generators.

B. MISMATCH CHARACTERISTICS

1. The Type-80 Noise Standards are made up of two waveguide sections and a cathode assembly. The waveguide sections are machined and assembled such that they form a 9-degree E-plane bend. The noise tube is inserted along the centerline of the rear section and emerges through the center of wide face of the front section at an angle of 9 degrees (Figure 10).

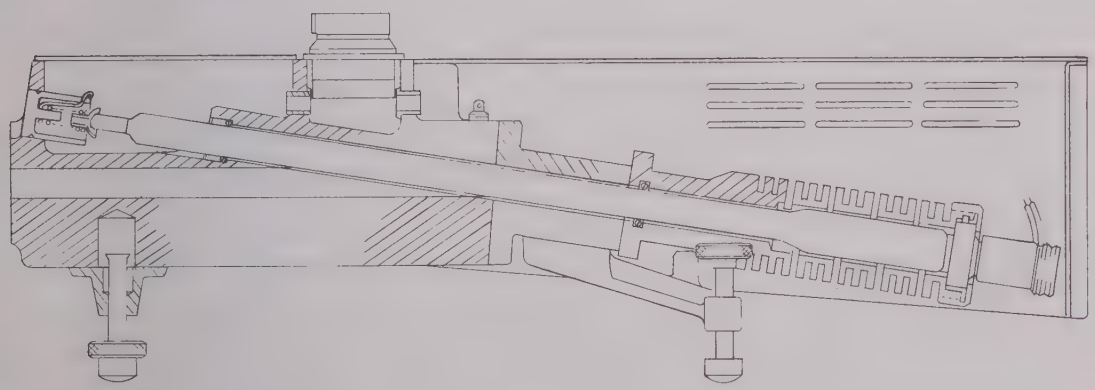


FIGURE 10. CUTAWAY VIEW OF NOISE STANDARD

2. The plasma of the noise tube is a good microwave absorber. The relatively low insertion angle of 9 degrees (as opposed to 10, 20, or 90 degrees in some generators) has the same effect as a long taper on a waveguide termination; that is, a low mismatch. This also explains the rise in VSWR at the lower band edge, since the effective taper is longer at higher frequencies. The RF absorption characteristic of the plasma also prevents the rather abrupt discontinuity at the waveguide junctions from having a significant effect on the mismatch.

3. Variations in wall thickness of the noise tube, and orientation with respect to the centerline of the long dimension of the guide also affect VSWR. The first condition is controlled by using low-loss glass tubing which has been shrunk on a mandrel and then centerless ground. Centering is assured by "O" rings in the two end sections.

C. STABILITY AND REPEATABILITY

1. These characteristics are a function of: (a) the noise output stability of the tube, (b) the mechanical stability of the noise tube with respect to the mount, and (c) the flange repeatability.

2. The noise tube in the mount is of DC filamentary design. The cathode is made up of a filament which is energized only during the starting time. Once the tube is ionized, filament power is removed. This, in effect, removes one possible variable, since the existence of filament current does affect anode current, which, in turn, has an effect on noise output (about 0.003 db/ma). The overall short-term stability of the noise tube and mount combination is in the order of $\pm$0.001 db after a half-hour warm-up.

3. Mechanical stability of the tube in the mount is ensured first by the "O" rings mentioned earlier, and, second by the cathode assembly. This assembly rigidly locks the tube in place and prevents shifting during normal handling. This assembly also ensures that, should the tube be removed for any reason, when it is returned to the mount, it will be in the same position and orientation as before its removal. This feature permits calibration of more than one tube in a mount, thus providing a spare in the event of a tube failure. Tests performed at the National Bureau of Standards have shown that removal and replacement of the noise tube results in a change in noise output of less than 0.001 db.

4. It will be noted that the flanges of the Type-80 Noise Standards are thicker than that found on most waveguide components; this is to provide rigidity and prevent distortion of the flange. Tests at the National Bureau of Standards have indicated that repeatability of the unit, after disconnecting and reconnecting, result in a noise output change of less than 0.001 db.

D. NOISE OUTPUT

1. The output of a noise source may be expressed in either of two forms: output noise temperature, or excess noise ratio (sometimes called relative excess noise temperature).

2. The noise temperature of a Type-80 Noise Standard is essentially the electron temperature of the gas, since the waveguide losses are relatively low. The noise power per unit bandwidth represented by a temperature is given by:

$$P_N = KT \tag{1}$$

where

T = temperature, ^oK,

K = Boltzmann's constant (1.38×10^{-23} joules/^oK),

P_N = power per unit bandwidth, watts/Hz.

3. In general, most noise measurement calculations are based on available power--that is, the power a source would deliver to a conjugately matched load. The temperature associated with this power is called the available output noise temperature. Typically, this number is in the order of $10,500^oK$.

4. The National Bureau of Standards has defined the term effective output noise temperature. This is the temperature associated with the power per unit bandwidth a source would deliver to a reflectionless or perfectly matched load. Effective output noise temperature is related to available output noise temperature by:

$$Tne = (1 - |\Gamma g|^2)\, T_A \tag{2}$$

where

Tne = effective output noise temperature, ^oK,

T_A = available output noise temperature, ^oK,

Γg = output reflection coefficient of noise source.

Since, for the Type-80 Noise Standards, the square of the reflection coefficient seldom exceeds 0.0006 (VSWR = 1.05), the effective output noise temperature is essentially identical to the available output noise temperature.

5. The output of a noise source is quite often expressed in terms of its excess noise ratio or, as it is sometimes called, relative excess noise temperature. This is usually expressed in db and is given by:

$$R_x = 10 \log \left(\frac{T_g}{T_o} - 1 \right) \tag{3}$$

where

R_x = excess noise ratio in db,

T_g = output noise temperature of the source, ^oK,

T_o = standard reference temperature, 290^oK.

Note that T_g can be either effective or available output noise temperature, although it is generally assumed to be available temperature. Typically, the excess noise ratio of a Type-80 Noise Standard is in the order of 15.5 db.

VII. CALIBRATION

A. FACTORY CALIBRATION

As received from the factory, the Type-80 Noise Standards are calibrated at three frequencies in the appropriate frequency band. These frequencies coincide with the N.B.S. calibration frequencies and are shown in Table 2. The results are given in terms of excess noise ratio with an overall, additive uncertainty of ± 0.2 db. In terms of noise temperature, this is about $\pm 500^{\circ}K$. The relationship between the two uncertainties is given by:

$$\Delta R_x = 10 \log \left(1 + \frac{\Delta T_g}{T_g - T_o} \right) \qquad (4)$$

B. N.B.S. CALIBRATION

The National Bureau of Standards will calibrate the Type-80 Noise Standards. The results are given in terms of effective output noise temperature and excess noise ratio. The uncertainty of the results are given as $\pm 250^{\circ}K$ or ± 0.1 db. N.B.S. will also calibrate at frequencies other than those listed in Table 2 at an increased fee.

TABLE 2
N.B.S. STANDARD CALIBRATION FREQUENCIES

Band	Waveguide Size	Calibration Frequencies (GHz)		
K_u	WR62 (RG-91/U)	13.5	15.0	17.0
X	WR90 (RG-52/U)	9.0	9.8	11.2
S*	WR284 (RG-48/U)	2.85	3.25	3.55

* Proposed, not yet in operation.

For further information, direct inquiries to:

Microwave Calibration Service REF. 252.31
Engineering Division
Radio Standards Laboratory
National Bureau of Standards
Boulder, Colorado 80301

VIII. MAINTENANCE

A. NOISE TUBE REPLACEMENT

Maintenance of the Type-80 Noise Standard is limited to replacement of the noise tube in the event of a failure. This is accomplished in the manner indicated under Section III of this handbook. Under no circumstances should any further disassembly of the Type-80 Noise Standards be attempted; this automatically voids the warranty.

B. FACTORY REPAIR

1. Should repair of the unit be required, return the Noise Standard to the factory in accordance with the following instructions.

2. Write to the Microwave Instruments Department of AIL, giving complete information concerning the nature of the failure and the manner in which the equipment was being used when failure occurred. Also provide TYPE and SERIAL numbers of the unit. Shipping instructions will then be supplied. The instrument should be packed and shipped in accordance with these instructions, and shipping charges prepaid. A failure report should accompany the equipment.

IX. PARTS LIST

Each Type-80 Noise Standard contains only one replaceable part. This is the gas-discharge tube. Table 3 lists the replacement tubes for the various Type-80 Noise Standards.

TABLE 3
REPLACEMENT TUBES FOR TYPE-80 NOISE STANDARDS

Noise Standard Part No.	Replacement Tube No.
8052	212515
8091	212843

WARRANTY

Except for tubes, fuses, and batteries which carry no warranty, Cutler-Hammer, in connection with equipment sold, agrees to correct any defect in workmanship or material that may develop during the period of one year from the date of shipment under proper or normal use and not in excess of the original manufacturer's life expectancy ratings, by its option to repair or to replace, F.O.B. point of shipment, the defective part or parts, and such correction shall constitute a fulfillment of all Cutler-Hammer liabilities in respect to said apparatus.